R. K. Eskew

Potato Flakes

Potato flakes is a term used to describe mashed potatoes which have been dehydrated on a drum drier by the process developed at the Eastern Utilization Research and Development Division of the Agricultural Research Service in Philadelphia. Drum drying of cooked potatoes for flour has been known for some 50 years. It was introduced into the United States from Germany shortly after World War I. Cooked potatoes have also been drum dried extensively in Germany for feed under government subsidy. Retention of individual cell structure is unimportant in these products. In contrast, if the dehydrated product is to be capable of reconstitution to an edible mash with a consistency equal to that of mash prepared from fresh potatoes the cells must remain largely unruptured. The release of free starch from broken cells contributes an undesirable pastiness. Cooke (1912) was one of the first investigators to recognize this principle.

BACKGROUND

More than a century ago a U. S. Patent was granted to Edwards (1845) for dehydrating mashed potatoes. Since then mashed potatoes have been dehydrated in many physical forms. Cooke (1912), Remmers (1918), Allen (1921), Stoddard (1922), Gano (1940), Nixon (1944), Kaufman *et al.* (1949), and others describe shreds or porous filaments. Heimerdinger (1926), Bowen (1931), Barker *et al.* (1943), Burton (1944), and Morris (1947), describe the production of a powdered mashed potato by spray drying. It was Bunimovitch and Faitelowitz (1936) who first reported that at a moisture content of about 40 per cent potatoes could be reduced to a moist friable powder permitting drying to a granular product without excessive cell rupture. Various methods for this first stage of drying (from 80 per cent to 40 or 50 per cent moisture) were subsequently proposed.

EARLY DRUM DRYING STUDIES

Of particular interest in connection with the flake process is the work of Jones and Greer (1940 and 1943), Barker (1941), and Barker *et al.*

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(1943). These investigators proposed the use of a drum drier to reduce the moisture content of mashed potato to a range between 40 and 65 per cent, followed by disintegration of the sheet and a final pneumatic drying step. Barker (1941) states that if moisture content is reduced to 45 per cent or lower, damage to cells may be found to occur, but that at a moisture content of 50 to 53 per cent no such damage is observed. Barker *et al.* (1943) investigated both a double drum drier and a single drum of the type used for making potato flour. They reported that the small rolls used for applying mash to the heated drum of the latter type damaged the potato cells; they further advised keeping drum temperatures below 266°F. The moist sheet was then held for two and one-half hours after which it became sufficiently friable to permit granulating by brushing through a sieve. Olson and Harrington (1955) used a small double drum drier for this partial drying and found it harmful to texture if temperatures above 212°F. were used.

In the foregoing work with drum driers the objective seemed invariably to have been the production of a granular product using drum drying only as a means of reducing the moisture to a point where granulation of the product became possible. It seems strange that nothing can be found in the literature prior to 1954 relative to drum drying mashed potatoes for food to a dryness suitable for storage and use.

The systematic study of the dehydration of mashed potatoes for food on drum driers was initiated by Cording *et al.* (1954). Their early work was done on a pilot plant double drum drier with six-inch diameter rolls. To obtain mash of good texture on reconstitution, it was necessary at that time to use potatoes of at least 20 per cent solids. After washing, peeling and trimming in the usual way, the potatoes were sliced in $^3/_4$-in. slabs and cooked in atmospheric steam for 12 to 15 minutes—a shorter cook than generally used for granules or flour. Mashing was effected in a planetary mixer as mashing rolls appeared to cause some cell rupture.

Double drum driers are not ordinarily used for materials with the physical properties of mashed potatoes. Feeding had to be accomplished by a continuous wiping action with a paddle to force the mash into the nip between the rolls and to continuously expose fresh mash to the heated drums thereby avoiding "case hardening" the surface of the mash. Dilution to a fluid consistency, permitting a more conventional method of application, damaged the cells.

Drum clearance was found to be of great importance. Clearances below 0.007 in. caused excessive cell rupture and yielded a pasty product, according to Willard and Cording (1957). Using a clearance of 0.013 in. the product was incompletely dried in one stage at a drum temperature of 289°F. but on further drying in air was reduced to a moisture content satisfactory for storage and for rapid rehydration to good mashed potatoes. With a clearance of 0.17 in. the product could be dried satisfactorily in a second stage but did not rehydrate to a mashed potato of suitable texture. Cording *et al.* (1954) found that depending somewhat on drum speed, temperatures as high as 335°F. could be used without scorching the product or inducing pastiness. Cording and Willard (1956) found that dilution of the mash made from very high solids potatoes, e.g. 24 per cent dry matter, to reduce solids to between 20 and 22 per cent, improved adhesion to the drum and gave a product having four per cent or lower moisture.

Although subsequent work by the same investigators showed a single drum drier of the type used for flour to be much superior to a double drum unit for dehydrating mashed potatoes, these early studies established at least two important principles relative to drum drying; (1) mashed potatoes can be dried to low moisture in one stage on a drum drier to give a product which yields on reconstitution a mash of good texture and flavor, and (2) the moisture content of the mash should be kept between 78 and 80 per cent in order to achieve good adhesion to the drum and low final moisture without scorching.

INFLUENCE OF COOKING ON TEXTURE

In order to rehydrate to an acceptable product, a dehydrated mashed potato must yield on reconstitution a mash which has substantially the same texture or "feel in the mouth" as a freshly prepared mash. Naturally the latter will vary greatly depending on the variety of potato used and the method of preparation. In general, high solids varieties such as Russet Burbank, especially when grown in the Rocky Mountain area, give a mealy somewhat fluffy mash: lower solids varieties, for example Katahdins, give a smoother mash. Regional texture preferences correspond roughly to the type of mash obtainable from varieties grown in those regions.

Preference may be for a mealy or a creamy mash, a thick or thin consistency or for a particular flavor; but seldom if ever for pasty texture such as results from too much free starch. Pastiness may result not only from free starch but from too low solids in the potatoes, from immaturity at harvest and also from the cooking procedure used.

Reeve (1954) studied the effects of different heat treatments on the gelation of starch in the potato cell and the resultant effect on texture. Cording *et al.* (1955) and Cording and Willard (1957) found that precooking of raw potato slices between 140° and 180°F. prior to cooking at higher temperatures until soft, enabled the making of a flake yielding a good texture from potatoes as low as 18.5 per cent solids (ca. 1.073 specific gravity). By varying the time and temperature of precooking, the texture of the reconstituted mash from Idaho grown Russet Burbanks could be varied over a wide range. It could be made "pasty," "desirably mealy" or "unpleasantly sandy." The most desirable precooking conditions were found to be about 20 minutes at 160°F. Later work by the same authors showed these conditions to be satisfactory for some 14 potato varieties. The cooking time should be varied between 16 and 40 minutes in atmospheric steam; the lower solids varieties requiring the longer time.

COOLING

Cording *et al.* (1959) reported that the benefits of precooking could be enhanced by cooling the precooked potatoes in water below about 75°F. for at least 15 minutes. Cooling precooked pieces for 20 minutes reduced the "blue value" (a measure of free starch) Mullins *et al.* (1955) as much as 60 per cent. In consequence the resulting flakes could be broken to a greater extent without impairment of texture of the reconstituted mash. Because of their tendency to give high blue values and a pasty mash, low solids varieties benefit especially by the cooling step interposed between precooking and cooking. Precooking followed by cooling are now standard procedures in the flake process and have made possible the commercial production of flakes in Midwestern and Eastern areas.

SELECTION OF RAW MATERIAL

To be suitable for flakes a potato should be of a variety which will yield a mash of good texture when made from the freshly cooked potato. Low solids potatoes of the type best for canning or salads are not well suited for flakes. Similarly, types usually grown in the Southeast for the early market and harvested before maturity should not be used.

Reducing sugars should not exceed one per cent on the fresh basis at the time of processing. Varieties which recondition well throughout the season are thus desirable. Good flakes have been made at the Eastern Utilization Research and Development Division from individual lots of the following varieties grown in twelve states:

California—Kennebec, Russet Burbank, White Rose
Idaho—Russet Burbank
Maine—Cherokee (Presque Isle), Green Mountain, Katahdin, Kennebec, Russet Burbank
Maryland—Cobbler (Eastern Shore)
Michigan—Russet Rural, Sebago
Minnesota—Cobbler and Red Pontiac (Red River Valley)
Montana—Russet Burbank

North Dakota—Russet Burbank (Walhalla)
New York—Katahdin, Russet Burbank
Pennsylvania—Katahdin, Russet Rural
Washington—Russet Burbank
Wisconsin—Cobbler (Rhinelander), Russet Burbank (Antigo)

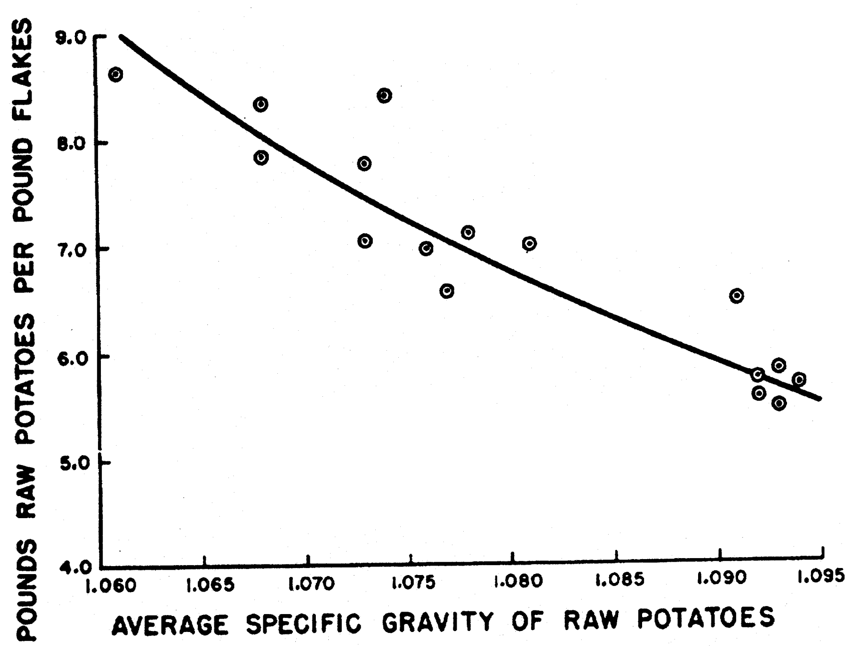

FIG. 75. EFFECT OF SPECIFIC GRAVITY OF RAW POTATOES ON YIELD OF FLAKES

Product quality is, of course, not the only consideration in selecting raw material. Yield is of prime importance and is markedly influenced by the solids content of the potato, as shown in Fig. 75. These data were taken from pilot plant operations (Cording *et al.* 1957). They thus represent relative rather than the absolute yields to be expected in large scale production.

POTATO FLAKE PROCESS

The manufacture of potato flakes may be thought of as becoming commercially feasible with the adaptation of the single drum drier to their production. Eskew *et al.* (1956) operated an integrated pilot plant and determined the basic engineering data from which they prepared cost estimates. They showed that potato flakes could be produced commercially at a cost enabling their profitable sale at a price equal to or lower

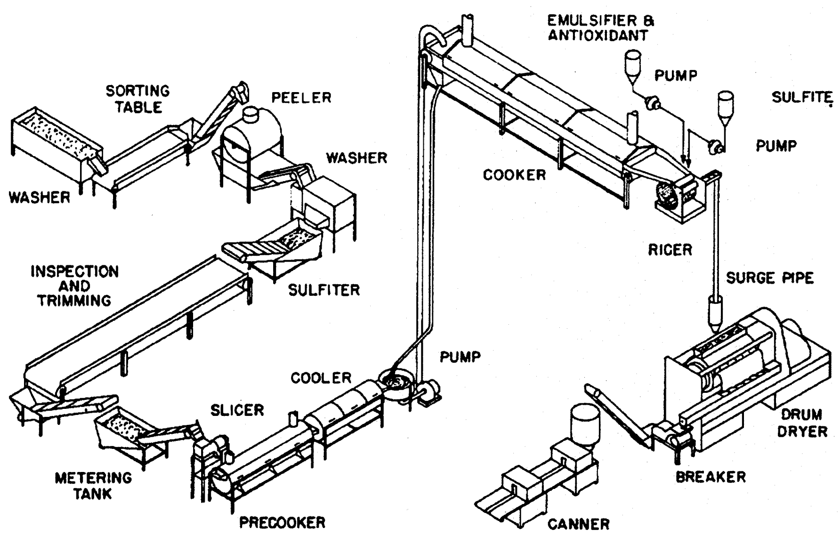

FIG. 76. POTATO FLAKE PROCESS.

than the then current price of competitive forms of dehydrated mashed potatoes.

Preparation and Cooking

Potatoes after washing are lye- or steam-peeled, trimmed, sliced to slabs approximately one-half inch in thickness, and then precooked for 20 minutes in water at 160°F. They are then cooked in atmospheric steam until just soft enough to rice. It generally requires 30 minutes for high solids starchy types and about 40 minutes for Katahdins and lower solids varieties. Overcooking is harmful to texture.

Various methods of ricing are used, but for good quality cell rupture must be kept to a minimum. A ricer designed by Hyde and Cording (1958) has given good results. It consists of a rotating perforated cylinder (17/64 in. diam. holes) on the outer surface of which two small solid rolls are driven at the same peripheral speed as the drum. The clearance between the drum and the first roll is just sufficient to permit acceptance of the cooked slices and to crush them lightly. The second roll is set close enough to force the potatoes through the perforations. A ribbon screw inside the perforated cylinder and rotating in the opposite direction discharges the product at one end. Pilot plant view of this design is shown in Fig. 77.

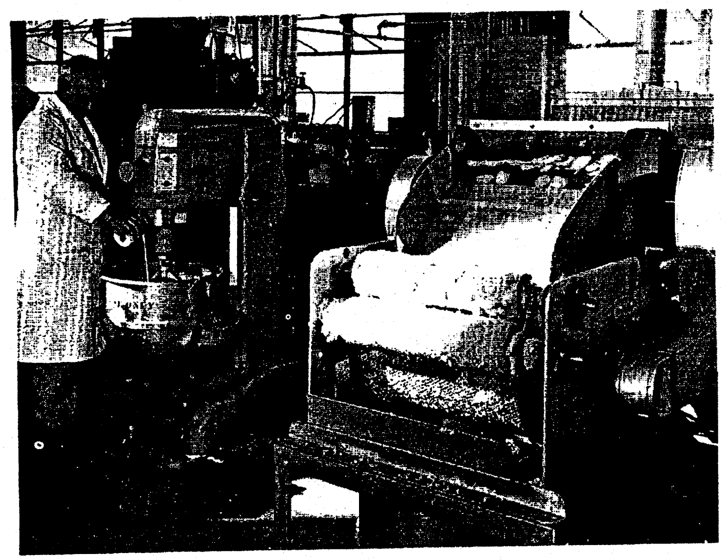

FIG. 77. DISCHARGE END OF COOKER SHOWING RICER.

Additives

Additives are preferably introduced before drying to improve flavor stability and texture. Amounts to be added per ton of mash are shown in Table 44.

TABLE 44

AMOUNT OF ADDITIVES USED PER TON OF MASHED POTATOES

Additives	Gm. per 2000 Lbs. Mashed Potato	Additive, Based on Solids in Mash (Assuming 21.5 Per cent Solids)
Glycerol monopalmitate	200	0.10%
Tenox VI[1,2]	150	47 p.p.m.
Skim milk solids	400	0.20%
Sodium sulfite	120	150–200 p.p.m. sulfite
Sodium bisulfite	40	

[1] Reference to a specific product does not imply an endorsement by the U. S. Dept. Agr. over others not mentioned.
[2] The identity and allowable concentration of antioxidant should be cleared by the Food & Drug Administration.

Drying

Drying can best be done on a single drum drier of the type commonly used in making potato flour. The mash is fed to the top surface of the drum by a two-way ribbon screw rotating in the opposite direction from the drum. Small diameter unheated rolls (Fig. 78.) progressively apply fresh mash to that already partially dried, thus filling interstices and building up a dense sheet. The peripheral speed of the rolls is the same as that of the drum and if their clearance from the drum is kept at about one-quarter of an inch, there is no apparent cell damage.

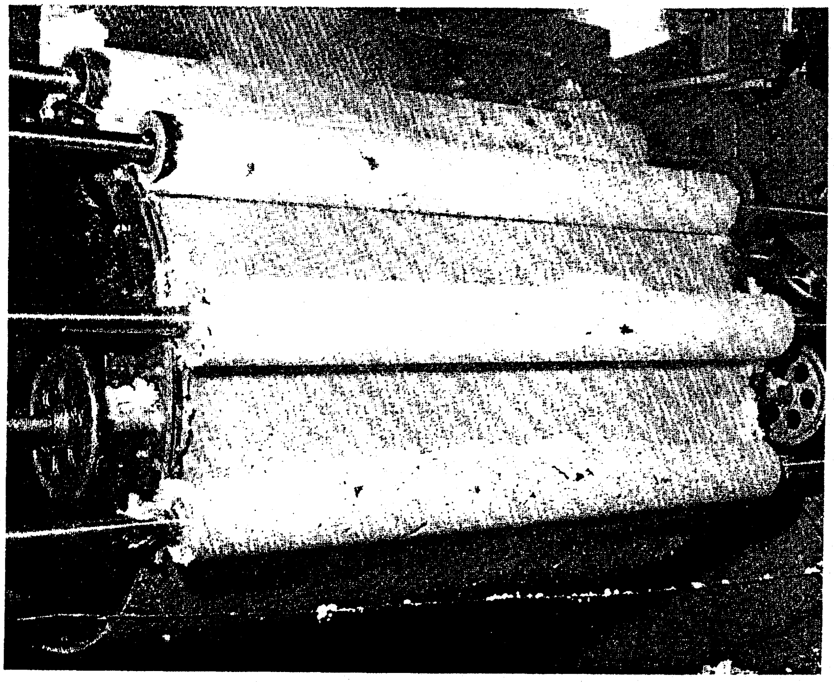

FIG. 78. WET MASH SIDE OF SINGLE DRUM DRIER SHOWING APPLICATOR ROLLS

A doctor knife removes the dried sheet, although in most cases when a good dense sheet is being made, it peels away from the drum just ahead of the knife leaving the surface quite clean. The discharge side of a commercial size potato flake drier is shown in Fig. 79. A screw conveyor breaks the sheet coarsely. The desired size is obtained by further breaking and screening.

BASIC DATA FOR EFFICIENT OPERATION OF THE DRUM DRIER

Drum drying of cooked potatoes is a comparatively simple operation, but to carry it out at a high production rate with good thermal efficiency and at the same time obtain a dense sheet without cell damage, requires careful control of a number of factors. Cording *et al.* (1957) have studied the effect of drum speed and solids content of the potato on production rate, sheet density and product moisture. Figure 80 shows how the product rate increases with both solids in the potato and drum speed. Although not shown in the graph, increase in solids content above 22 per cent may reduce output because the fluffy character of the resulting

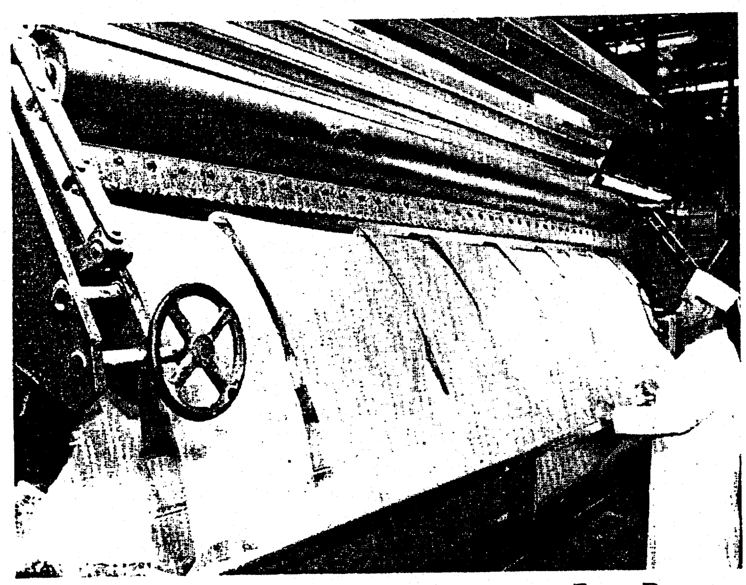

FIG. 79. DISCHARGE SIDE OF A COMMERCIAL POTATO FLAKE DRIER.

mash prevents good adherence to the roll. Experience has shown that a very high solids mash should be diluted to about 21 to 22 per cent solids to obtain good contact between sheet and drum and to form a dense sheet. Also, as shown in Fig. 81, high product rates, i.e., high drum speed, are accomplished at the expense of sheet density. This is pertinent because low density means higher packaging costs.

Figure 82 shows that at drum speeds above 2 r.p.m. product moisture rises. It might appear that moisture would decrease at speeds below 2 r.p.m.; however, it tends to rise. The very rapid increase in sheet density at these slow speeds causes the sheet to become overly dried on its inner surface and to separate from the drum before diffusion of the moisture can take place. An increase in steam pressure above 80 lbs. per sq. in. may also cause overdrying on the inner sheet surface to such an extent that the sheet may fall to the floor before completing its travel. The most favorable drying conditions are generally as follows: Solids in the mash between 20 and 22 per cent, steam pressure 75 to 80 lbs. per sq. in., drum speed about 2.5 r.p.m. This should give a dense sheet

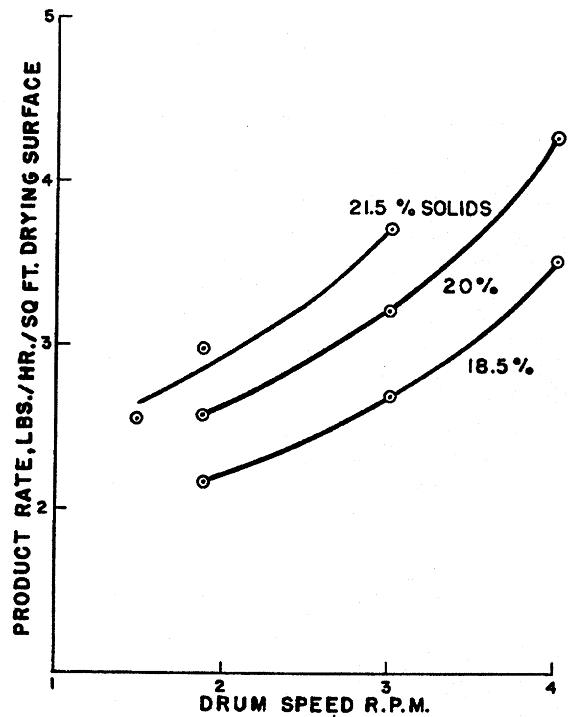

FIG. 80. EFFECT OF DRUM SPEED AND SOLIDS CONTENT OF POTATOES ON POTATO FLAKE PRODUCTION RATE

having between 5 and 6 per cent moisture. Strolle and Cording (1965) recommend this approximate range on the basis of the B.E.T. monolayer and storage tests.

PACKAGING AND STORAGE LIFE

Flakes for retail use are generally packed in a foil-laminate envelope inside a rigid carton. No storage tests have been made at the Eastern Utilization Research and Development Division on flakes so packaged. However, Drazga *et al.* (1964) report that potato flakes of about 6 per cent moisture, packed in air and containing 50 p.p.m. B.H.A. plus B.H.T. as antioxidant and 200 p.p.m. sulfite, kept well at room temperature for approximately 6 months, in cans.

COMMERCIAL STATUS

Potato flake production has enjoyed a steady growth since flakes were first made in Maine in 1958. Today they are made in 8 states and estimated domestic capacity is 50,000 tons of flakes annually. They are also made commercially in 14 plants in 9 foreign countries.

POTATO FLAKELETS

The bulk density of potato flakes can be increased by breaking only to a maximum of about 23 lbs. per cubic foot; further breaking impairs texture of the reconstituted mash. There has long been a need for a dehydrated mashed potato of high bulk density which would yield on reconstitution a product of quality equal to that made from flakes. A patent was issued to Eskew (1962) on a process whereby flakes could be modified to give a product bulk density as high as 50 or more pounds per

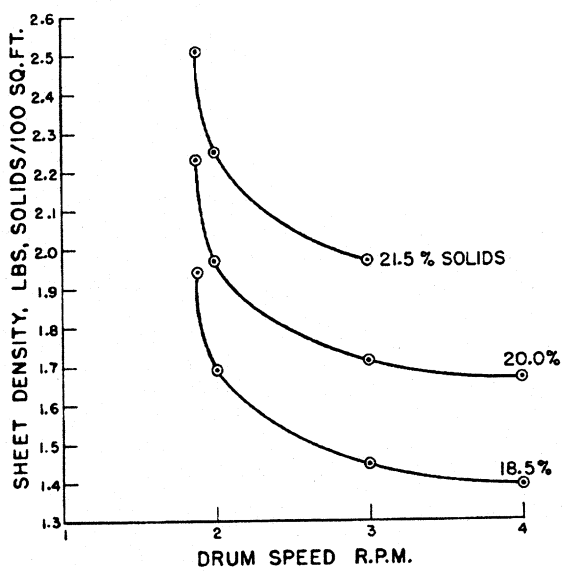

FIG. 81. EFFECT OF DRUM SPEED ON POTATO FLAKE SHEET DENSITY

cu. ft., without impairment of texture of the reconstituted product. According to Eskew and Drazga (1962) the product, contrary to the implications of the name, is not simply small flakes but consists largely of laminated flake fragments created by intimately mixing small flakes with sufficient mashed potato to give a moisture of about 30 per cent. The mixture is then "manipulated," rubbed together and compacted into small laminates. The appearance of potato flakelets in contrast to finely broken flakes is shown in Figs. 83 and 84. The authors reported that flakelets have a liquid absorptive capacity about 10 per cent higher than the flakes from which they are made. Thus the same size serving of mash can be made with a smaller quantity of flakelets than of flakes. Figure 85 shows the potato flakelet process as it would be carried out commercially.

The process through the cooking operation is the same as for flakes. In making flakelets, approximately 93 per cent of the cooked potatoes are riced, dried on the drum drier and the product after it is broken is mixed with the other seven per cent of the cooked potatoes. These proportions will naturally depend on the moisture in the flake component and that desired in the mixture. For Western Russet Burbanks containing 21 per cent solids the mixture should have a moisture content of approximately 30 per cent. The proper moisture will depend upon the variety and solids content of the potatoes. In most cases it will lie between 28 and 32 per cent. This is well below the moisture used for granulating. Thus the mixture is free flowing and can be compacted in the manipulator without formation of hard balls. A continuous manipulator as used in pilot plant development is shown in Figs. 86 and 87. The same design on a larger scale would be suitable for commercial use.

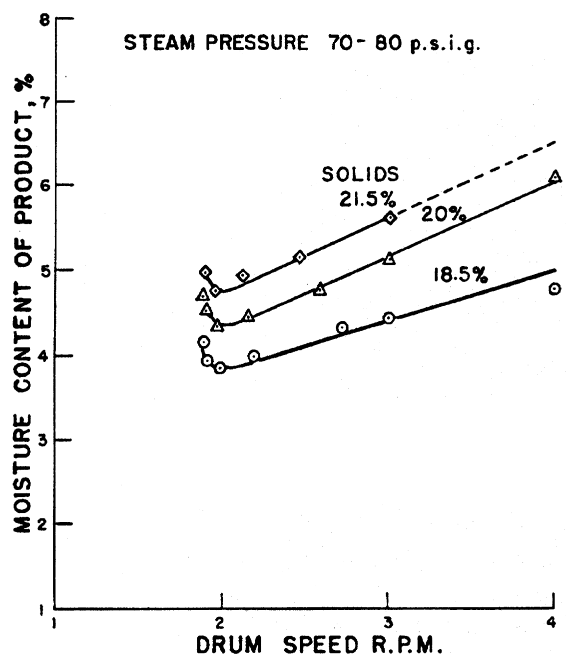

FIG. 82. EFFECT OF DRUM SPEED ON MOISTURE CONTENT OF POTATO FLAKES

Additives

Sulfites and antioxidants (if used) are added to the mash fraction which is to be drum dried; whereas the emulsifier, to the extent of $1^1/_2$ per cent on the basis of solids in the finished product, is advantageously incorporated into the smaller mash fraction which is cooled and mixed with the broken flakes.

Drum Drying

In drying the flake component, drum speeds as high as six r.p.m. may be employed; sheet density is unimportant since the flakes become laminated in the manipulator. Moreover sheet moisture need not be lower than 8 or 10 per cent. These two factors make drum drier capacity almost double that for flakes.

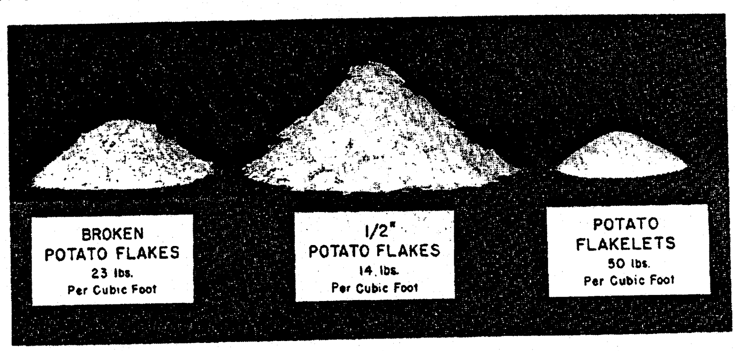

FIG. 83. RELATIVE BULK OF EQUAL WEIGHTS OF FINELY BROKEN FLAKES, FLAKES AND FLAKELETS.

Final Drying

The mixture is reduced to about six per cent moisture by passing over a vibrating bed drier. About 90 seconds are required at an air temperature of 230°F. and velocity of 120 f.p.m.

Costs

Claffey *et al.* (1961) have given details of the process as it would be carried out commercially. They estimate that primarily because of reduced bulk, flakelets could be made and packed in No. 10 cans at about $1^1/_2$ cents per pound cheaper than flakes similarly packed. Even if flakelets are packed in nitrogen their cost is estimated at about 1 cent per pound cheaper than air-packed flakes containing antioxidant.

Drazga *et al.* (1964) showed flakelets and flakes to have the same shelf life when similarly packed. They showed also that flakelets, protected only by nitrogen packing, kept as well as samples containing Tenox IV.

Although flakelets have not yet been made commercially, their quality, density, stability, and low cost suggest a significant potential.

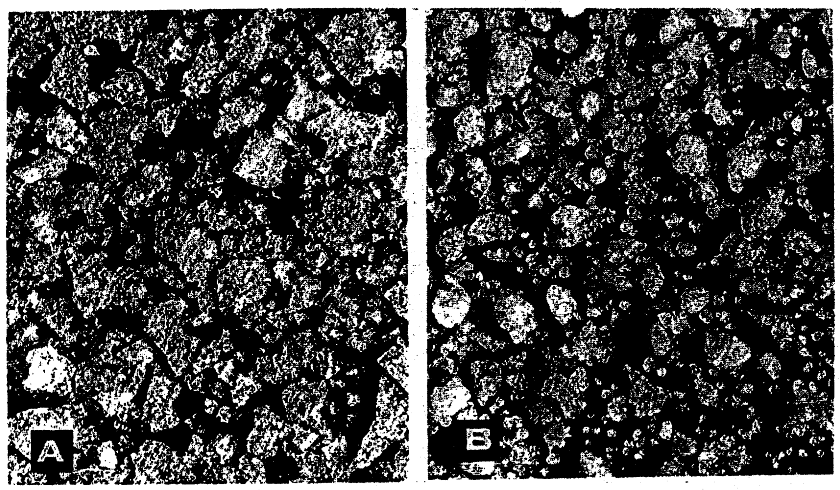

FIG. 84. POTATO FLAKES (A) CONVERTED TO FLAKELETS (B).

These two samples have the same screen analysis. Nevertheless, (A) has a bulk density of 26.8 lbs/cu.ft. and (B), because of its laminated character, has a bulk density of 51 lbs/cu.ft.

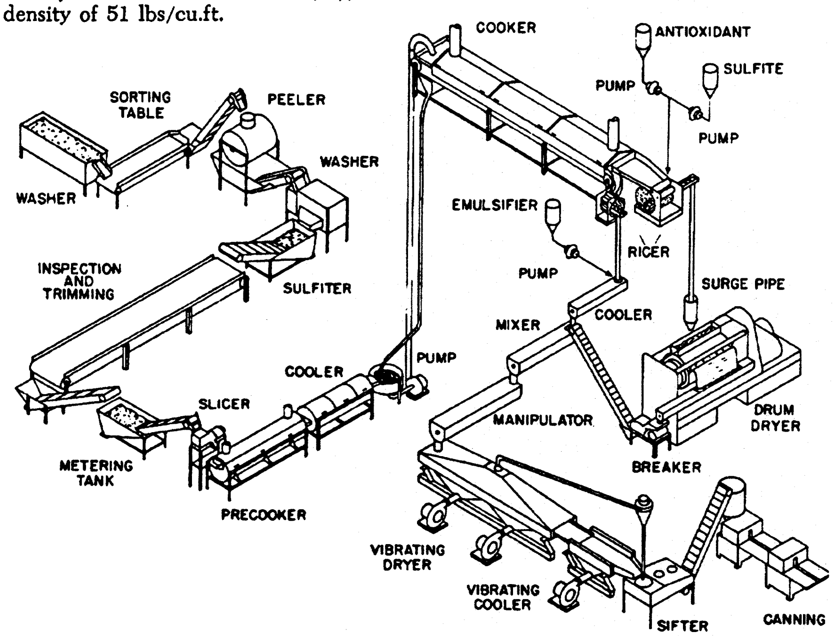

FIG. 85. POTATO FLAKELET PROCESS.

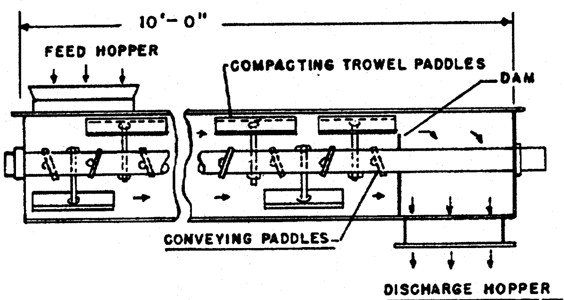

FIG. 86. PILOT PLANT MANIPULATOR

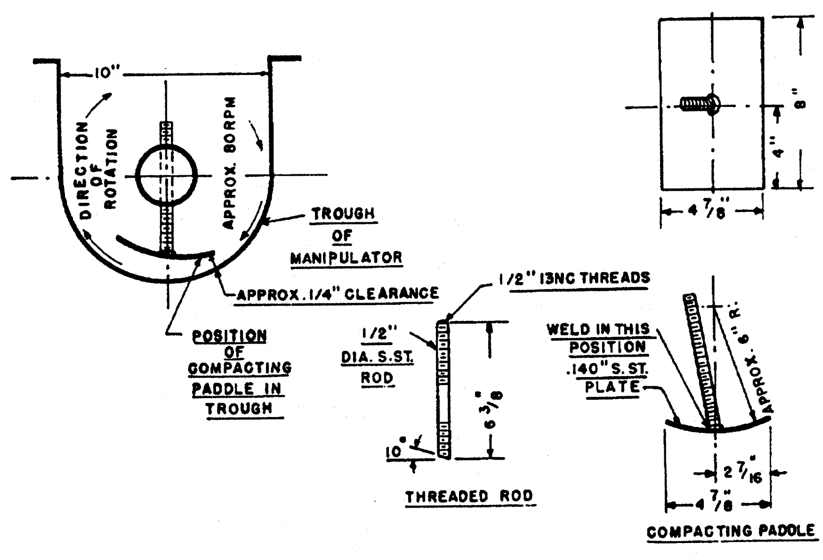

FIG. 87. DETAIL OF PILOT PLANT MANIPULATOR

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